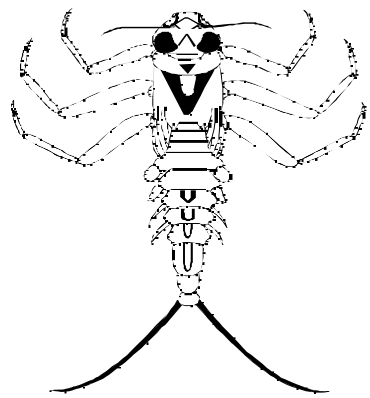
Bio-monitoring of Water Quality Using Aquatic Invertebrates and In-stream Habitat and Riparian Condition Assessments: Status Report for Wilson's Creek and Skegg's Branch, Wilson's Creek National Battlefield, Missouri 1988-2004



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1.0 INTRODUCTION

The National Park Service (NPS) began monitoring the aquatic invertebrates of Wilson's Creek and Skegg's Branch in 1988, with three years of baseline data collected for the period 1988-1990 (Harris et al. 1991). Sporadic sampling continued during the period 1992-1995, with funding provided by the Midwest Regional Office of NPS. Concentrated monitoring efforts began in 1996, following the creation of the Prairie Cluster Prototype Long-term Ecological Monitoring Program, now known as the Heartland Inventory and Monitoring Network and Prairie Cluster Prototype Monitoring Program – a base-funded science program to monitor natural resources at Wilson's Creek National Battlefield and sixteen other Midwestern NPS units. In-stream habitat and riparian condition assessments were conducted in 2002 and 2003 to monitor the quality of habitat available to and other factors influencing aquatic invertebrate communities within Wilson's Creek and Skegg's Branch. The purpose of this report is to summarize aquatic invertebrate monitoring data collected from 1988-2004, and the results of the in-stream habitat and riparian condition assessments.

Benthic invertebrates are the most common group of organisms used to assess water quality (Rosenberg and Resh 1993). They are useful as indicators because they represent a diverse group of relatively long-lived, sedentary species that react strongly and often predictably to human influences on aquatic systems (Cairns and Pratt 1993). The objectives of this bio-monitoring program are to determine the annual status of stream invertebrate communities in order to assess the overall biotic integrity of Wilson's Creek and Skegg's Branch and to detect changes through time in aquatic invertebrate communities. The in-stream habitat and riparian condition assessments will give us a better understanding of the environment in which the aquatic communities have evolved.

1.1 Background

Wilson's Creek, a tributary of the James River, meanders from north to south for about 4.8 km through the center of Wilson's Creek National Battlefield (Harris et al.1991). The creek enters the James River 1.6 km south of the battlefield, ultimately flowing into Table Rock Lake. The James River Basin drains the Springfield Plateau region of the Ozark Highlands. Skegg's Branch, a tributary, joins Wilson's Creek near the center of the battlefield. The Wilson's Creek drainage basin lies in southwestern Missouri, in Greene and Christian Counties (Black 1997). Wilson's Creek originates in Springfield, the third largest city in Missouri (pop. 151,010); Skegg's Branch originates near the town of Republic (pop. 9378).

The natural vegetation of the area is a mosaic of oak-hickory forest and woodland, tallgrass prairie and limestone glade communities, with forested river corridors (Gremaud 1986; Nelson 1987). The area is part of Omernick's (1987) Ozark Highlands eco-region, which is topographically characterized by open and high hills.

Pollution History.--Black (1997) gives an extensive review of the pollution history of Wilson's Creek, which is summarized here. In the early 1800s Wilson's Creek was a clear, spring-fed stream. However, by the late 1800's water conditions had deteriorated precipitously due to raw sewage release from the developing city of Springfield. Springfield's first modern sewage treatment plant opened in 1910 releasing effluent into a tributary of Wilson's Creek. The sewage treatment plant was moved to its current location along Wilson's Creek in 1959 and upgraded significantly in 1962, 1978, and 1993. Phosphorous removal was added to the system in 1996 and upgraded in 2001. Current capacity of the treatment plant is 42.5 million gallons per day of treated sewage with effluent released directly into Wilson's Creek. Development within the Wilson's Creek watershed between treatment plant upgrades often out-paced the benefits from increased treatment plant capacity, resulting in cyclic re-occurrence of poor water quality preceding treatment plant improvements.

The State of Missouri declared approximately 29 km of Wilson's Creek as water-quality impaired (Missouri Department of Natural Resources 1998) Data from Nimmo et al. (1989) and others demonstrated toxicity in Wilson's Creek, which has been corroborated by reports of biological impoverishment (Missouri Department of Natural Resources 2002). The state attributes this toxicity to non-point source pollution from urban areas and considers Wilson's Creek a high priority for development of a Total Maximum Daily Load (TDML), as required by the Clean Water Act.

2.0 METHODS

2.1 Aquatic Invertebrate Sampling

The details of field and laboratory procedures are described in Peterson et al. (1999), and summarized below.

Monitoring Sites.--Harris et al. (1991) established three monitoring sites within the park, two along Wilson's Creek and one on Skegg's Branch (Figure 1). Criteria for site selection probably included capturing stream quality at points of entry and exit from the park, coverage of major tributaries within the park and ease of access. Five replicate Surber samples were collected at each site during each sampling event.

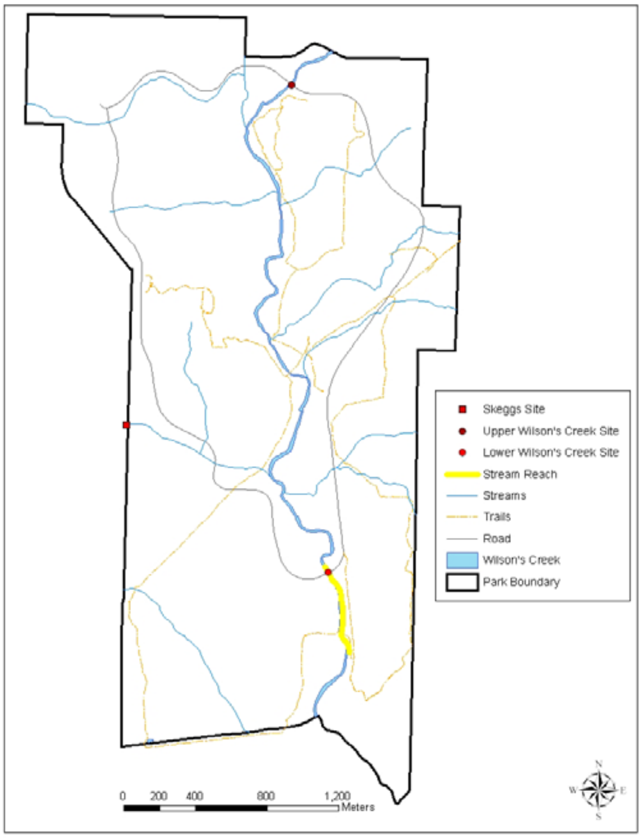

Figure 1. Aquatic Invertebrate monitoring sites at Wilson's Creek National Battlefield, MO.

Sampling Frequency and Timing.--Five replicate samples were collected from each of three sites at approximate monthly intervals during a summer sampling window defined by growing degree days (i.e. days with average daily temperature above 10°C). For Wilson's Creek National Battlefield, normal average daily temperatures fall within this range for the period 1 June through 10 August (National Weather Service). The samples included in this report were collected between 5 June and 3 September.

Field Sampling.--Benthic invertebrate samples were collected from shallow riffle areas of a stream with a Surber sampler following methods outlined by Peterson et al. (1999). Colorado State University investigators collected aquatic invertebrate samples for the period 1988-1990 (Harris et al. 1991). Park staff collected aquatic invertebrate samples for the period 1996-2004. To minimize disturbance to a site prior to sampling, samples were collected from the most downstream riffle at a site first, and progressed upstream until five replicate samples were collected. A small rake (trowel) was used to dislodge organisms from the substrate inside the sampler. Cobble inside the sampler was scrubbed with a vegetable brush to dislodge additional organisms. Invertebrates were carefully removed from the sampler and placed in labeled jars containing 80 % ethyl alcohol. Samples were then prepared for shipping and sent to the laboratory for species identification and enumeration.

Laboratory Procedures.—Aquatic invertebrates were identified and enumerated by Dr. Boris Kondratieff's laboratory, Colorado State University for the period 1988-1990 (Harris et al.

1991); and by Dr. Charles Rabeni's laboratory, Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri-Columbia for 1996-2004. Invertebrates were identified to the lowest taxonomic level possible, which was generally to genus.

Community Indices.--The monitoring protocol recommended using a suite of four community indices to describe changes in community structure (Table 1) (Peterson et al. 1999). Peterson (1996) used Pearson correlation comparisons and a Principal Components Analysis of the correlation matrix to select four indices from a possible list of nine metrics. We have included Taxa Richness and EPT Richness in this summary for purposes of comparison with aquatic invertebrate monitoring data from other sources.

Table 1. Metrics used to characterize the aquatic invertebrate communities of Wilson's Creek and Skegg's Branch, Wilson's Creek National Battlefield, MO and chosen as indicative of changing water quality through time. An asterisk indicates metrics originally selected by Peterson (1996).

Metric(Reference)	Definition	Expected Response
Taxa Richness (Resh and Grodhaus 1983)	Number of taxa present per sample.	Lower richness indicates declining water quality.
Family Richness* (Resh and Grodhaus 1983)	Number of families present per sample.	Lower richness indicates declining water quality.
Family Diversity* (Shannon-Wiener Index: Shannon and Weaver 1949)	$H' = -\Sigma(n_i / N)*\ln(n_i / N)$ N is the total number of individuals in a sample; n_i is the total number of individuals in the ith family.	Includes a measure of richness and evenness. Lower diversity indicates declining water quality.
Family Biotic Index* (Hilsenhoff 1988)	$FBI = \Sigma n_i a_i / N$ N is the total number of individuals in a sample, n_i is the total number of individuals in a family, and a_I the tolerance value for the ith family.	This index weights the relative abundance of each family by its relative pollution tolerance value to determine a community score. Pollution-tolerant species are weighted more heavily than pollution-sensitive species in the index. Higher FBI indicates declining water quality.
EPT Richness (Resh and Grodhaus 1983)	Number of Ephemeroptera, Plecoptera, and Trichoptera taxa present per sample.	The majority of taxa in these three orders are pollution sensitive. Lower EPT richness indicates declining water quality.
EPT Ratio* (Resh and Grodhaus 1983)	EPT/(EPT + Chironomidae) The number of EPT individuals in a sample divided by this sum plus the number of Chironomidae.	The EPT ratio varies between 0 and 1. Ratio values close to 0 describe low EPT densities relative to Chironomidae and EPT densities, and indicate declining water quality.

2.2 In-stream Habitat and Riparian Condition Assessment

Details on procedures for assessing in-stream habitat and riparian condition are described in Peitz (draft), and summarized here. Eleven transects spaced equal distances apart along a 512 m reach were used to assess in-stream habitat and riparian condition. The first two transects were located downstream of the aquatic invertebrate sample site. The third transect was located at the sample site with the remaining eight upstream at 51.2 m intervals. Water quality measurements, dissolved oxygen, conductivity, pH, temperature and water clarity were taken at a representative location along the reach before entry into the stream to complete other assessment work. This kept observers from impacting water quality results. Dissolved oxygen (DO) and temperature were measured using a YSI 55 meter. Conductivity, relative conductivity and pH were measured using a YSI 63 meter. Water clarity or cloudiness caused by suspended or dissolved materials in the water was measured using a 120 cm Secchi tube.

In-stream discharge, flow stage, fluctuation rating and channel morphology were assessed and recorded for the stream reach at the completion of all in-stream habitat and riparian condition assessments. The presence and type of channel alterations as well as sedimentation and excessive algae problems was noted. Also noted was the amount and date of all recent rains if any. Pools located within the reach were recorded as belonging to one of four classes depending depth: class 1, pool > 3 ft; class 2, pool > 2 ft; class 3, pool >1 ft; and class 4, pool is shallow and pool/riffle/run/bend ratio determined. Channel sinuosity and a stream degradation rating were determined for the reach.

In-stream habitat and riparian condition parameter were assessed at each transect and results recorded in one of three categories; in-stream, stream bank or riparian zone. Stream bank and riparian zones were assessed on the left and right side of the stream separately. Right and left banks were determined when looking downstream. Both in-stream habitat and stream bank assessments were done for an area five meters either side of each transect. Stream bank was the area between the wetted edge of the stream and point of bank full (the point were the stream would leave its banks at flood stage). The riparian zone was assessed for an area 10 m^2 centered on each transect and starting at the bank full mark of the stream. Coverage of vegetation, woody debris and other structures were determined for in-stream, stream bank and riparian areas. Substrate type and embeddedness were determined and recorded for both in-stream and stream bank areas. The occurrence of filamentous algae, floating vegetation, rooted vascular plants and large woody debris were recorded. Upper and lower bank stability, severity of grazing damage if any and overall assessment of buffer zone condition was also made for each side of a transect. The depth of the Thalweg and substrate present at the point of the Thalweg were recorded during the 2003 survey.

2.3 Statistical Analysis Methods

Aquatic Invertebrate Analysis.--The invertebrate indices for Wilson's Creek were compared graphically using means and an estimate of variance. This analytical approach was chosen over other statistical analysis options because of the imbalance among years in the number of samples collected. Specifically, in 1988, 1990 and 2000 when samples were collected on only one date. During 1996 and 1998 samples were collected on two different dates within the year. All other years, samples were collected on three or more occasions. Also, within some years June samples tended to be more variable than July, August or September samples (Appendix A). On each date, two sites were sampled with five replicates taken at each site.

The invertebrate indices for Skegg's Branch were compared graphically using means and an estimate of variance as well. The intermittent nature of Skegg's Branch precluded the collection of samples on three different sample dates within a year. The exception being years 2001 and 2004 when aquatic invertebrate samples were collected on three different dates. As with Wilson's Creek, five replicates were collected from Skegg's Branch on each sample date. The exception being 14 July 2004 when only four replicate samples were collected.

Annual means and standard errors for Wilson's Creek and Skegg's Branch were calculated from means for each sample site and date. These means and standard errors were graphed and used to make annual water quality comparisons for Wilson's Creek and Skegg's Branch within the battlefield. As more data is collected, annual variations and trends in the water quality of Wilson's Creek and Skegg's Branch will be investigated using more rigorous statistical methods. Both, the correlation of data collected at the same site through time and the lack of independence of samples collected at a site on any given date will be considered in future analysis.

In-stream Habitat and Riparian Condition Assessment Analysis.--Annual means were calculated for parameters measured within the stream reach. Using these means an overall mean and standard error for each parameter was calculated. Mean parameter values give us a baseline from which we can assess the influences of the physical and chemical environment on the aquatic invertebrate communities within Wilson's Creek. As more data is collected, the relationship between in-stream habitat and riparian conditions with invertebrate communities in Wilson's Creek will be investigated using more rigorous correlation analysis.

3.0 RESULTS

Aquatic Invertebrates.--The annual aquatic invertebrate indices for Wilson's Creek at Wilson's Creek National Battlefield, Missouri are reported on Table 2 and displayed in Figure 2. The raw data are reported by sampling event and site in Appendix A as well.

Table 2. Mean (± SE) metric values for the aquatic invertebrate communities in Wilson's Creek, Wilson's Creek National Battlefield, Missouri from 1988 to 2004.

Aquatic Invertebrate Index	1988 n = 2	1989 n = 4	1990 n = 2	1996 n = 4	1997 n = 6	1998 n = 4	1999 n = 6	2000 n = 2	2001 n = 6	2002 n = 6	2003 n = 6	2004 n = 6
Taxa Richness	12.00 (1.40)	16.40 (0.83)	13.60 (0.20)	20.95 (1.44)	18.77 (1.79)	18.50 (1.48)	14.50 (1.12)	10.30 (0.30)	14.63 (0.61)	13.40 (0.75)	12.60 (0.78)	9.87 (1.04)
Family Richness	10.00 (1.00)	12.50 (0.52)	9.60 (0.20)	10.80 (1.10)	12.17 (1.45)	11.80 (1.00)	8.93 (0.71)	5.80 (0.20)	8.57 (0.47)	8.53 (0.26)	7.73 (0.28)	7.23 (0.71)
Family Diversity	1.47 (0.16)	1.09 (0.09)	0.72 (0.01)	1.15 (0.08)	1.23 (0.08)	1.62 (0.08)	1.27 (0.08)	0.83 (0.06)	1.45 (0.07)	1.38 (0.04)	1.35 (0.05)	1.43 (0.11)
EPT Richness	3.90 (0.30)	3.10 (0.68)	1.40 (0.00)	5.15 (0.44)	4.57 (0.84)	5.65 (0.43)	3.10 (0.71)	2.50 (0.10)	4.60 (0.20)	3.83 (0.28)	3.83 (0.51)	1.87 (0.38)
EPT Ratio	0.61 (0.09)	0.26 (0.03)	>0.01 (>0.01)	0.27 (0.06)	0.25 (0.08)	0.56 (0.02)	0.37 (0.10)	0.11 (0.03)	0.39 (0.02)	0.28 (0.04)	0.37 (0.13)	0.33 (0.08)
Family Biotic Index	5.33 (0.13)	5.61 (0.09)	6.61 (0.11)	5.85 (0.18)	5.94 (0.19)	5.50 (0.05)	6.17 (0.31)	6.61 (0.08)	5.77 (0.11)	5.87 (0.18)	5.83 (0.35)	5.24 (0.25)

Richness, the number of taxa at a given taxonomic level, indicates that water quality of Wilson's Creek improved significantly in 1996 and 2001, followed by two years of relatively stable water conditions (Table 2 and Fig. 2). However, by year three after improvements were recorded, water quality appeared to be in decline based on EPT Taxa Richness (Fig. 2a), Family Richness (Fig. 2d) and Total Taxa Richness (Fig. 2d) values. All three levels of richness have annually approached, equaled or exceeded the baseline levels, especially 1990 values. However, all three values were less likely to equal or exceed baselines levels in more recent years.

EPT Ratio (Fig 2b) and Family Diversity (Fig. 2c) values have similar cyclic patterns as the richness values. However, our Family Biotic Index (Fig. 2e) values indicate that the water quality of Wilson’s Creek has remained stable through time. The EPT Ratio, a measure of the number of individuals in the EPT taxa to the number of pollution tolerant Chironomids, had declined significantly in 1990, one of our baseline years and in 2000. But these values have remained constant since 2000 based on means and overlapping standard error values. Family Diversity (Fig 2c) values declined in 1990 and 2000 as well. However, this metric has improved or remained constant each year since 2000.

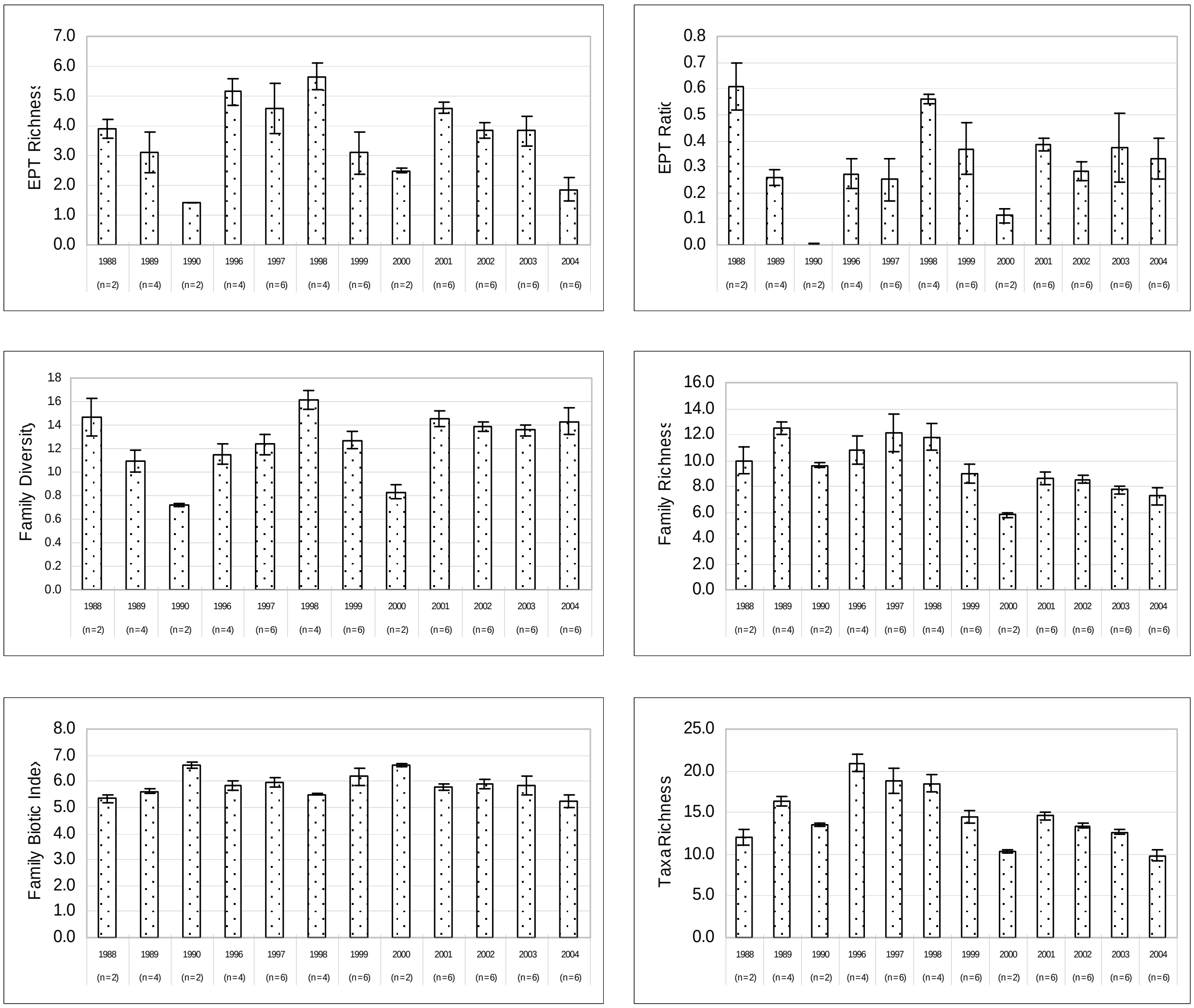

Figure 2. Mean (± SE) metric values for the aquatic invertebrate communities in Wilson’s Creek, Wilson’s Creek National Battlefield, Missouri from 1988 to 2004.

The annual aquatic invertebrate indices for Skegg’s Branch at Wilson’s Creek National Battlefield are reported on Table 3 and displayed in Figure 3. The raw data are reported by sampling event and site in Appendix A as well. EPT Richness (Fig 3a) values were somewhat erratic for Skegg’s Branch with lower values recorded in 1999, 2002 and 2004. Both Family Richness (Fig 3d) and Total Taxa Richness (Fig 3f) have demonstrated annual declines since 1997.

Table 3. Mean (± SE) metric values for the aquatic invertebrate communities in Skegg's Branch, Wilson's Creek National Battlefield, Missouri from 1988 to 2004.

Aquatic Invertebrate Index	1988 n = 1	1989 n = 2	1990 n = 1	1997 n = 2	1999 n = 2	2001 n = 3	2002 n = 2	2003 n = 1	2004 n = 4
Taxa Richness	14.00	23.50	23.80	25.80	20.00	18.73	15.70	14.00	11.88
		(0.50)		(0.60)	(1.80)	(0.53)	(1.30)		(2.08)
Family Richness	12.00	17.30	17.00	17.30	12.50	10.87	8.00	8.20	8.68
		(0.30)		(1.10)	(0.70)	(0.74)	(0.20)		(1.00)
Family Diversity	1.92	1.92	1.86	1.96	1.70	1.76	1.35	1.24	1.70
		(0.02)		(0.02)	(0.09)	(0.12)	(0.07)		(0.12)
EPT Richness	3.80	6.20	5.60	5.10	2.80	4.87	2.80	4.40	2.45
		(0.40)		(0.50)	(0.40)	(0.18)	(0.20)		(0.90)
EPT Ratio	0.72	0.55	0.58	0.27	0.29	0.45	0.33	0.45	0.44
		(0.16)		(0.03)	(0.09)	(0.02)	(0.05)		(0.10)
Family Biotic Index	5.81	5.69	5.70	6.12	5.50	5.21	5.41	6.24	4.95
		(0.11)		(0.19)	(0.12)	(0.09)	(0.09)		(0.07)

Our EPT ratio (Fig 3b) values, while erratic indicate that water quality of Skegg's Branch has remained the same or improved slightly since 1997. However, recent EPT ratio values are still significantly below our baseline year values. Family Diversity (Fig. 2c) values have remained relatively constant through time with only slight declines noted in 2002 and 2003. Our Family Biotic Index (Fig. 2e) values indicate that the water quality of Skegg's Branch has remained constant through time.

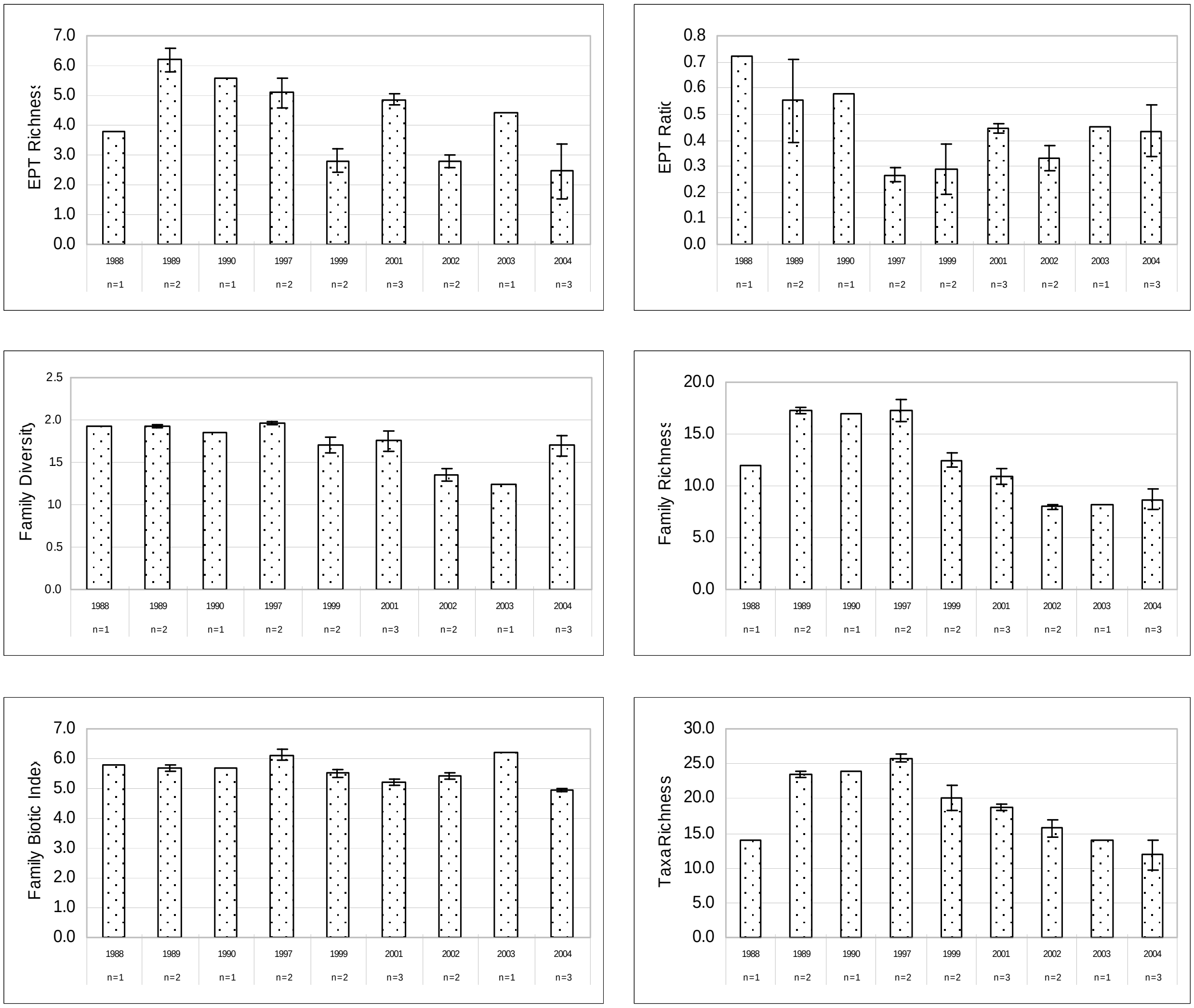

Figure 3. Mean (+ SE) metric values for the aquatic invertebrate communities in Skegg's Branch, Wilson's Creek National Battlefield, Missouri from 1988 to 2004.

In-stream Habitat and Riparian Condition Assessments.--Average habitat conditions for Wilson's Creek at Wilson's Creek National Battlefield, Missouri during 2002-2003 are shown in Table 4. Flow in the creek was determined to be moderate with a recent rain event of 6.40 cm recorded during our 2002 assessments. The fluctuation rating for the creek was determined to be minor to moderate. Sinuosity of Wilson's Creek is low to moderate. Excessive sedimentation was not noted within the assessment reach. However, excessive algae growth was noted during the 2002 assessment. Flow within the assessment reach has been altered somewhat to accommodate a road bridge. The pool/riffle/run/bend ratio was recorded as occasional, 8-15, which is good. Class 1 and class 2 pools occurred occasionally too commonly in the reach. Class 3 pools were rare to occasional in the reach. Class 4 pools were recorded occasionally within the reach. Stream degradation was moderate within the reach assessed. The condition of the buffer zone along the reach was poor to good, mostly fair and grazing damage was nonexistent.

Table 4. Mean ($\pm$ SE) values for habitat parameters measured in Wilson's Creek at Wilson's Creek National Battlefield, Missouri in 2002 and 2003.

	Mean	Std. Err	Minimum	Maximum	Range
	Water chemistry parameter				
Water temperature (C^o)	22.60	1.60	21.00	24.20	3.20
Dissolved oxygen (mg/l)	7.95	0.92	7.03	8.86	1.83
Conductivity (uS/cm)	792.50	77.50	715.00	870.00	155.00
pH	7.74	0.12	7.62	7.86	0.24
Water clarity (cm)	120.00	0.00	120.00	120.00	0.00
	In-stream habitat parameter				
Stream width (m)	14.75	0.26	12.00	20.60	8.60
Thalweg depth (m)-2003 only	0.84	--	0.27	1.65	1.38
Canopy cover (%)	35.44	10.67	24.77	46.11	21.34
In-stream vegetation cover (%)	3.77	3.23	0.00	15.00	15.00
Small woody debris cover (%)	6.43	5.61	0.00	37.50	37.50
Overhanging vegetation cover (%)	11.41	1.77	0.00	37.50	37.50
Undercut bank (%)	17.02	2.70	0.00	85.00	85.00
Boulder cover (%)	13.52	0.98	0.00	62.50	62.50
Artificial structure cover (%)	0.50	0.32	0.00	3.50	3.50
	Stream bank parameter				
Height (m)	2.18	0.13	1.20	5.20	4.00
Slope (^{o})	31.00	0.23	11.00	75.00	64.00
Grass/forb cover (%)	33.23	3.91	3.50	85.00	81.50
Shrub/vine cover (%)	10.27	0.52	0.00	37.50	37.50
Understory trees cover (%)	8.49	1.83	0.00	37.50	37.50
Overstory tree cover (%)	15.19	6.38	0.00	62.50	62.50
Bare soil cover (%)	48.40	8.81	3.50	85.00	81.50
Bare rock cover (%)	26.25	3.16	0.00	85.00	85.00
Woody debris cover (%)	12.51	7.88	0.00	85.00	85.00
	Riparian parameter				
Grass/forb cover (%)	37.72	5.22	3.50	62.50	59.00
Shrub/vine cover (%)	19.77	5.48	0.00	62.50	62.50
Tree seedling cover (%)	4.19	1.44	0.00	15.00	15.00
Understory tree cover (%)	12.38	3.28	0.00	37.50	37.50
Overstory tree cover (%)	21.53	9.01	0.00	85.00	85.00

Average water quality measurements taken at a representative location along the assessment reach are given in Table 4. These measurements may have been influenced by runoff from recent rain events in 2002. However, water quality was not influenced by recent rain in 2003. Stream discharge within the reach averaged 0.21 m^3/s and average stream depth at the point of discharge was 0.44 m. Average Thalweg depth for the total reach was 0.84 m. Cobble made up 44% of the substrate within the reach followed by gravel (35%), boulder (12%), bedrock (8%) and sand (2%). Thirty-nine percent of the substrate materials greater than 64 mm in diameter present in Wilson's Creek were embedded greater than 75%, much of this substrate was near the creek's bank. Another 39% of the substrate material was embedded less than 25%. Twelve percent of the in-stream substrate material was embedded 25-50% and 9% was embedded 50-75%. Figure 3 illustrates the average depth and flow at ¼, ½ and ¾ of the distance across the river.

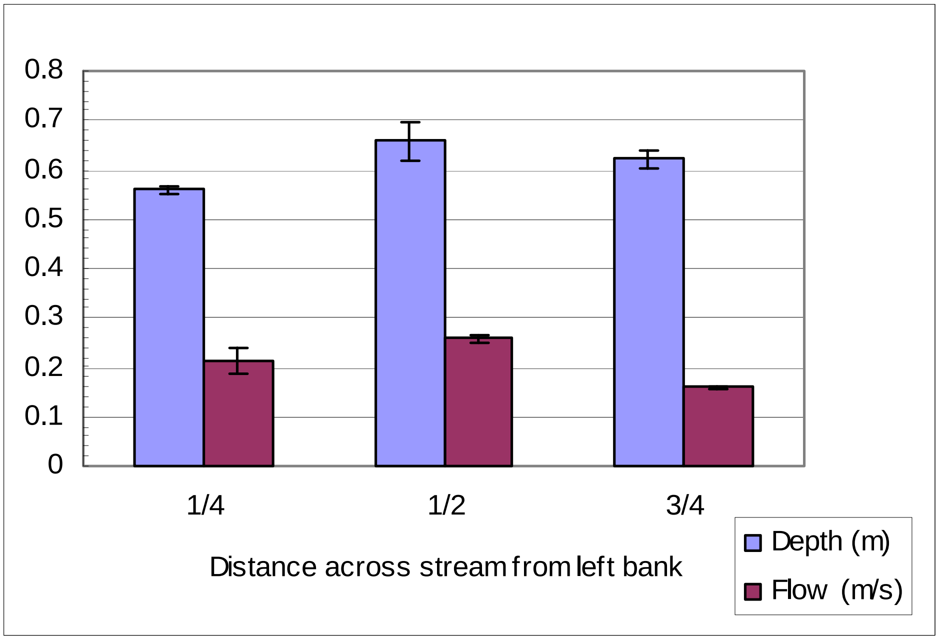

Figure 4. Mean (+ SE) stream depth and flow at ¼, ½ and ¾ of the way across Wilson's Creek from left bank. Measurements were taken within Wilson's Creek National Battlefield, Missouri in 2002-2003.

Average cover of vegetation, brush and small woody debris, overhanging vegetation, undercut banks, boulders and artificial structures in Wilson's Creek within our assessment reach are given in Table 4. Within the assessment reach, canopy coverage average approximately 35% across years. Five logs between 0.1 and 0.3 m in diameter were recorded in the reach in 2002. Another log 0.3 – 0.6 m in diameter was recorded as well. However, in-stream large woody debris increased significantly in 2003, the year a tornado passed through the assessment reach. Three logs greater than 0.8 m in diameter were recorded, three between 0.3 and 0.6 m, and seven between 0.1 and 0.3 m. Rooted vascular plants were recorded as nonexistent to occasionally observed along the assessment reach depending on which transect one was at. However, rooted vascular plants occurred only rarely along most of the reach. Filamentous algae occurred occasionally to commonly along the assessment reach. Floating vegetation was nonexistent within the reach.

Lower stream bank stability was rated as poor to good, mostly fair. Upper stream bank stability was rated as poor to good as well. However, almost half of the upper stream bank stability was rated as good. The dominant stream bank substrates were silt (70%) and gravel (11%). The dominant cover is bare soil (48%) followed by a vegetation cover of grass/forbs (33%; Table 3). The riparian area along the stream bank was dominated by forest/woodland (40%) and upland-prairie (39%) habitat types.

4.0 DISCUSSION

In summary, it appears that the water quality of Wilson's Creek within Wilson's Creek National Battlefield, follows an almost cyclic pattern related to improvements made to a wastewater treatment plant in its drainage basin. Improvements in water quality occurred in 1996 and 2001, two years when phosphorous removal upgrades were completed on the treatment plant. Rapid housing growth in both the drainage basin and in the overall area serviced by the wastewater treatment plant seems to be outpacing improvements to the plant. Generally, water quality declined two to three years after plant improvements. Runoff and the contaminants contained within from the ever increasing impervious surfaces within the drainage basin also contribute to a depressed aquatic invertebrate fauna within Wilson's Creek. It may well be that runoff currently contributes a larger amount of contaminants to Wilson's Creek than the wastewater treatment plant. However, the altered flow of Wilson's Creek can still be attributed to the effluent released by the treatment plant.

Increases in sediments and contaminants in runoff flowing into Skegg's Branch may very well be starting to depress the aquatic invertebrate fauna of this stream as well. Housing developments in the city of Republic Missouri lie within the drainage basin of Skegg's Branch and contribute to the increasing sedimentation in runoff flowing to the stream. Increasing impervious surfaces in and around these housing developments also add contaminants to runoff as well as alter the fluctuation patterns of Skegg's Branch.

When looking at results of our monitoring efforts it is important to keep in mind that our data for Wilson's Creek and Skegg's Branch has not been compared to reference streams in the region, and the observed changes are only relative to conditions observed previously. However, Wilson's Creek is listed as a 303d impaired waterway by the state of Missouri (Missouri Department of Natural Resources, Division of Environmental Quality 2002). Therefore, a depressed aquatic invertebrate community or a community with an altered make-up is expected. This listing of Wilson's Creek as a 303d waterway is based on unknown toxicity.

An expansion of the water quality monitoring within the battlefield included chemical and physical measures in 2002-2003. This has allowed us the opportunity to establish a baseline on which to measure changes in in-stream habitat conditions in the future. The effects these changes have on the invertebrate communities, our biological measure of water quality in Wilson's Creek can now be better assessed. Changes in the aquatic invertebrate communities are often related to changes in in-stream substrate composition and structure (invertebrate habitat), which are influenced by runoff from areas upstream. Changes in building practices and what is allowed to enter Wilson's Creek from a wastewater treatment plant will affect aquatic invertebrate communities and the quality of water they represent. We are scheduled to reassess in-stream habitat and riparian conditions in 2007-2008.

5.0 MANAGEMENT IMPLICATION

With only small portions of Wilson's Creek and Skegg's Branch flowing through Wilson's Creek National Battlefield, active management by battlefield staff would affect little change in water quality of these streams. However, battlefield staff could help improve water quality by working with land owners and city officials upstream on ways to expand riparian buffer zones to control what runoff enters Wilson's Creek and Skegg's Branch. City officials could also implement or expand efforts to sweep streets to reduce the amount of material allowed to enter the creek. Battlefield staff should continue to work with organizations, concerned citizens and city officials to ensure that the latest technologies are used to minimize contaminants allowed to enter Wilson's Creek from a wastewater treatment plant located in its drainage basin. The long history and continuing efforts with water quality monitoring in Wilson's Creek and Skegg's Branch provides a sound tool to recognize both a rapid deterioration of water quality as well as a chronic decline.

6.0 ACKNOWLEDGEMENTS

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Appendix A. Mean (± Std Dev) values for the aquatic invertebrate metrics calculated for Wilson's Creek and Skegg's Branch, Wilson's Creek National Battlefield, Missouri by date and sample site.

Date	N	Family Diversity	Family Richness	FBI	EPT Ratio	EPT Richness	Taxa Richness
			Wilson's Creek Upper				
8/15/88	5	1.31 (0.42)	11.0 (3.39)	5.46 (0.54)	0.70 (0.20)	4.2 (1.10)	13.4 (3.58)
6/26/89	5	1.05 (0.22)	13.0 (1.41)	5.68 (0.13)	0.20 (0.06)	2.0 (0.00)	16.0 (1.41)
8/15/89	5	0.86 (0.13)	12.2 (1.30)	5.71 (0.23)	0.21 (0.05)	3.6 (0.55)	16.4 (1.82)
6/27/90	5	0.71 (0.19)	9.8 (2.59)	6.72 (0.36)	> 0.01 (>0.002)	1.4 (0.55)	13.8 (2.59)
6/25/96	5	0.96 (0.24)	9.2 (1.79)	5.86 (0.15)	0.17 (0.05)	4.2 (0.84)	19.0 (3.54)
8/23/96	5	1.32 (0.15)	12.8 (2.05)	5.87(0.34)	0.36 (0.13)	5.8 (1.30)	22.2 (2.86)
6/05/97	5	1.20 (0.39)	9.4 (3.21)	6.04 (0.32)	0.06 (0.06)	2.4 (2.07)	17.2 (6.46)
7/15/97	5	1.12 (0.20)	11.6 (2.51)	6.49 (0.32)	0.15 (0.13)	4.4 (1.67)	18.2 (5.89)
9/03/97	5	1.49 (0.41)	16.2 (2.28)	5.37 (0.53)	0.52 (0.23)	6.0 (0.71)	24.0 (2.74)
7/08/98	5	1.77 (0.15)	14.4 (4.51)	5.53(0.46)	0.57 (0.12)	6.8 (1.48)	22.6 (5.77)
8/28/98	5	1.42 (0.09)	10.8 (1.64)	5.55 (0.61)	0.52 (0.24)	5.2 (1.10)	17.0 (2.12)
6/08/99	5	0.96 (0.22)	7.2 (1.10)	7.05 (0.26)	0.10 (0.08)	1.2 (0.84)	11.4 (3.21)
7/09/99	5	1.20 (0.36)	8.0 (3.61)	7.03 (0.31)	0.37 (0.29)	2.0 (1.87)	12.6 (7.02)
8/17/99	5	1.44 (0.10)	10.2 (1.30)	5.96 (0.64)	0.55 (0.28)	4.6 (0.89)	16.6 (4.28)
		Family Diversity	Family Richness	FBI	EPT Ratio	EPT Richness	Taxa Richness
8/23/00	5	0.89 (0.23)	5.6 (0.89)	6.69 (0.40)	0.14 (0.11)	2.4 (1.52)	10.0 (1.73)
6/28/01	5	1.55 (0.22)	8.4 (1.14)	6.12 (0.29)	0.36 (0.13)	4.6 (0.89)	13.8 (1.64)
7/18/01	5	1.39 (0.12)	6.4 (1.82)	5.87 (0.63)	0.41 (0.17)	3.8 (0.84)	12.4 (2.51)
8/21/01	5	1.62 (0.16)	9.8 (1.92)	5.42 (0.27)	0.46 (0.15)	4.4 (1.14)	16.8 (4.44)
6/07/02	5	1.33 (0.23)	8.6 (1.67)	5.17 (0.35)	0.15 (0.07)	3.2 (0.45)	13.6 (2.07)
7/15/02	5	1.40 (0.28)	8.8 (2.59)	5.99 (0.55)	0.35 (0.21)	4.6 (0.89)	14.6 (4.04)
8/07/02	5	1.34 (0.43)	9.6 (1.14)	6.46 (0.47)	0.31 (0.20)	3.6 (1.14)	16.0 (2.12)
9/05/02	5	1.27 (0.28)	6.8 (0.84)	5.80 (0.74)	0.38 (0.25)	3.0 (1.00)	12.0 (2.45)
10/10/02	5	1.30 (0.19)	7.2 (1.79)	5.14 (0.39)	0.42 (0.11)	3.8 (1.30)	12.6 (2.07)
6/18/03	5	1.20 (0.33)	8.0 (1.41)	6.33 (0.88)	0.18 (0.12)	2.2 (1.10)	12.0 (2.34)
7/23/03	5	1.38 (0.29)	8.0 (2.12)	6.35 (0.34)	0.20 (0.12)	3.8 (0.84)	13.4 (1.34)
7/31/03	5	1.36 (0.35)	7.0 (0.71)	6.23 (0.44)	0.36 (0.14)	5.4 (1.34)	12.8 (1.30)
8/13/03	5	1.48 (0.08)	7.6 (1.52)	5.94 (0.50)	0.37 (0.12)	4.2 (1.30)	13.8 (1.10)
8/27/03	5	1.29 (0.22)	6.2 (1.30)	6.08 (0.45)	0.30 (0.18)	4.0 (1.87)	12.2 (1.64)
6/16/04	5	1.23 (0.25)	7.2 (0.84)	5.63 (1.32)	0.15 (0.11)	0.8 (0.45)	9.4 (1.82)
7/14/04	5	1.38 (0.29)	6.4 (1.14)	5.73 (1.15)	0.20 (0.10)	1.6 (0.89)	9.4 (3.58)
8/02/04	5	1.01 (0.60)	5.2 (2.39)	5.26 (2.47)	0.23 (0.13)	1.6 (1.52)	7.4 (3.91)
			Wilson's Creek Upper – kick-net sample				
9/05/02	1	1.72	10.0	6.20	0.32	5.0	13.0
10/10/02	1	1.18	7.0	5.35	0.24	3.0	11.0
7/31/03	1	0.82	6.0	6.67	0.17	4.0	10.0
8/13/03	1	1.17	8.0	6.79	0.12	4.0	13.0
8/27/03	1	1.24	6.0	6.73	0.14	3.0	9.0
			Wilson's Creek Lower				
8/15/88	5	1.62 (0.28)	9.0 (2.65)	5.20 (0.36)	0.52 (0.26)	3.6 (0.89)	10.6 (2.61)
6/26/89	5	1.18 (0.17	11.2 (1.30)	5.34 (0.10)	0.32 (0.12)	2.0 (0.00)	14.6 (1.34)
8/15/89	5	1.29 (0.09)	13.6 (1.82)	5.70 (0.10)	0.30 (0.05)	4.8 (0.84)	18.6 (1.82)
6/27/90	5	0.73 (0.08)	9.4 (1.82)	6.50 (0.04)	> 0.01 (>0.001)	1.4 (0.55)	13.4 (1.82)
6/27/96	5	1.25 (0.20)	8.6 (1.67)	5.41 (0.26)	0.38 (0.12)	4.6 (0.89)	18.2 (4.97)
8/23/96	5	1.07 (0.13)	12.6 (1.52)	6.26 (0.18)	0.18 (0.07)	6.0 (1.41)	24.4 (3.91)
6/05/97	5	0.92 (0.15)	7.6 (2.07)	5.87 (0.13)	0.05 (0.04)	1.8 (1.30)	12.4 (3.71)
7/15/97	5	1.28 (0.16)	16.4 (1.95	6.40 (0.30)	0.25 (0.06)	6.6 (0.89)	23.6 (3.65)

Appendix A. continued.

Date	N	Family Diversity	Family Richness	FBI	EPT Ratio	EPT Richness	Taxa Richness
9/03/97	5	1.39 (0.18)	11.8 (3.27)	5.46 (0.39)	0.46 (0.17)	6.2 (1.48)	17.2 (5.07)
7/08/98	5	1.73 (0.14)	12.2 (1.48)	5.35(0.14)	0.59 (0.08)	5.8 (0.45)	18.6 (2.97)
8/28/98	5	1.54 (0.12)	9.8 (2.05)	5.57 (0.37)	0.57 (0.22)	4.8 (1.48)	15.8 (5.81)
6/08/99	5	1.18 (0.27)	7.8 (0.84)	6.01 (0.52)	0.06 (0.04)	1.6 (1.14)	14.2 (2.28)
7/09/99	5	1.43 (0.22)	8.6 (1.52)	5.88 (0.64)	0.51 (0.15)	3.8 (0.45)	13.4 (3.29)
8/17/99	5	1.43 (0.19)	11.8 (1.48)	5.07 (0.43)	0.63 (0.19)	5.4 (0.55)	18.8 (1.92)
8/23/00	5	0.77 (0.22)	6.0 (1.22)	6.53 (0.27)	0.09 (0.05)	2.6 (0.55)	10.6 (1.52)
6/28/01	5	1.46 (0.09)	8.8 (1.48)	5.49 (0.25)	0.42 (0.15)	4.6 (1.67)	14.6 (0.82)
7/18/01	5	1.55 (0.19)	9.2 (1.92)	5.73 (0.45)	0.39 (0.14)	5.2 (0.84)	14.6 (3.21)
8/20/01	5	1.16 (0.39)	8.8 (3.03)	5.98 (0.58)	0.28 (0.17)	5.0 (1.22)	15.6 (5.03)
6/07/02	5	1.40 (0.09)	7.8 (1.92)	5.63 (0.84)	0.20 (0.09)	3.0 (0.71)	10.6 (1.52)
7/15/02	5	1.26 (0.43)	8.2 (2.59)	5.99 (0.39)	0.31 (0.15)	4.6 (1.67)	13.0 (2.24)
8/07/02	5	1.56 (0.41)	8.2 (1.48)	5.99 (0.50)	0.39 (0.11)	4.0 (1.00)	12.6 (2.07)
9/05/02	5	1.44 (0.29)	7.2 (0.45)	5.48 (0.61)	0.50 (0.26)	4.6 (0.55)	12.6 (1.95)
10/10/02	5	1.47 (0.16)	8.4 (2.07)	5.11 (0.26)	0.50 (0.13)	5.2 (0.84)	14.6 (2.19)
6/18/03	5	1.35 (0.44)	8.2 (1.30)	6.20 (0.53)	0.12 (0.08)	2.6 (1.52)	14.2 (2.68)
7/23/03	5	1.22 (0.24)	8.2 (1.79)	6.09 (0.57)	0.37 (0.16)	5.4 (1.14)	13.2 (2.95)
7/31/03	5	1.20 (0.18)	6.6 (1.34)	5.96 (0.23)	0.36 (0.04)	5.2 (1.48)	12.4 (2.41)
8/13/03	5	1.47 (0.14)	6.4 (0.55)	4.09 (0.35)	1.00 (0.00)	4.8 (1.30)	9.0 (0.71)
8/27/03	5	1.31 (0.15)	7.8 (0.84)	6.01 (0.52)	0.36 (0.13)	6.2 (1.92)	14.2 (1.64)
6/16/04	5	1.77 (0.26)	10.4 (1.14)	5.67 (0.51)	0.49 (0.20)	3.2 (1.10)	14.8 (2.05)
7/14/04	5	1.60 (0.12)	7.2 (1.92)	4.13 (0.57)	0.65 (0.38)	2.8 (0.84)	8.6 (3.29)
8/02/04	5	1.60 (0.35)	7.0 (2.55)	5.02 (0.46)	0.26 (0.32)	1.2 (1.30)	9.6 (4.39)
Wilson's Creek Lower – kick-net sample							
9/05/02	1	1.73	8.0	5.53	0.52	2.0	12.0
10/10/02	1	1.30	8.0	5.38	0.32	6.0	11.0
7/31/03	1	1.77	10.0	4.85	0.68	7.0	14.0
8/13/03	1	1.21	5.0	4.13	1.00	5.0	8.0
8/27/03	1	0.66	5.0	6.72	0.09	2.0	10.0
Skegg's Branch							
8/15/88	5	1.92 (0.28)	12.0 (3.39)	5.81 (0.55)	0.72 (0.21)	3.8 (0.84)	14.0 (4.58)
6/26/89	5	1.90 (0.13)	17.0 (1.87)	5.58 (0.51)	0.71 (0.14)	5.8 (0.84)	23.0 (1.58)
8/15/89	5	1.94 (0.14)	17.6 (2.70)	5.79 (0.74)	0.39 (0.12)	6.6 (1.14)	24.0 (3.08)
6/27/90	5	1.86 (0.05)	17.0 (2.35)	5.70 (0.18)	0.58 (0.10)	5.6 (1.67)	23.8 (2.86)
6/05/97	5	1.95 (0.16)	16.2 (3.77)	5.93 (0.17)	0.24 (0.12)	5.6 (3.65)	26.4 (9.76)
7/09/97	5	1.98 (0.13)	18.4 (2.51)	6.23 (0.53)	0.30 (0.10)	4.6 (1.82)	25.2 (5.17)
6/08/99	5	1.79 (0.15)	11.8 (3.96)	5.38 (0.35)	0.38 (0.20)	2.4 (1.14)	18.2 (6.14)
7/09/99	5	1.61 (0.45)	13.2 (1.79)	5.63 (0.57)	0.19 (0.21)	3.2 (1.30)	21.8 (3.49)
6/29/01	5	1.83 (0.32)	11.8 (1.10)	5.31 (0.21)	0.42 (0.21)	4.6 (0.89)	18.2 (3.11)
7/19/01	5	1.92 (0.14)	11.4 (1.34)	5.29 (0.37)	0.43 (0.11)	4.8 (1.48)	18.2 (1.92)
8/21/01	5	1.52 (0.30)	9.4 (2.88)	5.04 (0.37)	0.49 (0.18)	5.2 (0.84)	19.8 (4.60)
6/07/02	5	1.42 (0.36)	8.2 (2.49)	5.50 (0.27)	0.28 (0.15)	3.0 (1.00)	14.4 (3.51)
7/15/02	5	1.28 (0.48)	7.8 (2.39)	5.32 (0.41)	0.38 (0.19)	2.6 (0.89)	17.0 (3.67)
7/18/03	5	1.24 (0.56)	8.2 (3.90)	6.24 (0.79)	0.45 (0.29)	4.4 (3.05)	14.0 (8.03)
6/16/04	5	1.91 (0.18)	10.6 (0.55)	5.00 (0.90)	0.36 (0.25)	3.8 (0.84)	16.0 (1.87)
7/14/04	4	1.50 (0.58)	7.3 (2.06)	5.05 (1.12)	0.32 (0.39)	0.8 (0.96)	9.3 (2.36)
8/02/04	5	1.68 (0.24)	8.2 (2.17)	4.81 (1.17)	0.63 (0.28)	2.8 (1.30)	10.4 (4.45)